Free space optical communication system for indoor applications based on printed circuit board design

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Article Info

Article history:

Received Aug 27, 2021
Revised Dec 1, 2021
Accepted Dec 9, 2021

Keywords:

Light-emitting diode
Phototransistor
Printed circuit board
Variable resistance

ABSTRACT

This study clarified an overview of wired and wireless optical communication system block diagram with practical applications. Free-space optical (FSO) communication is a trending field that is rising so fast to replace electromagnetic waves in a communication, so we have presented a theoretical circuit as an example and modified it to fit and work in communication purposes, simulation is used and then practical work is done and printed circuit board (PCB) is designed. Light emitting diode (LED) have been used as transmitter and Photo Transistor as a receiver and variable resistance to change voltage sent to the LED that indicates the change in the transmitted signal.

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1. INTRODUCTION

The bit error rate (BER) is optimized with four-wave mixing (FWM) optical wavelength division multiplexing systems. The main target of work is to achieve the highest quality of services by reducing the BER effects. They have outlined the different optical multiplexing schemes such as orthogonal frequency division, wavelength division multiplexing (WDM), and dense wavelength division multiplexing (DWDM) schemes [1]-[8]. The applications of FWM is presented in order to achieve a minimum BER. The link budget and receiver sensitivity design are studied for different optical fiber lengths and signal attenuation to show the maximum Q-factor value and corresponding minimum BER values. Mathematical analysis, computer, and simulation programs are performed to estimate the optimum fiber optic cable length that achieves max. Q-factor value and min. BER values in the presence of non return to zero code modulation formats [9]-[18].

They have presented a competing survey about the BER optimization in optical fiber communication systems [19]-[25]. The BER is estimated mathematically in the presence of nonlinear distortion interaction and amplified spontaneous emission effect [26]-[30]. Return to zero, non return to zero signal generators are coupled with optical modulators for 8-bit sequence of (10101100) at power variations values from 15 dBm to 20 dBm to test the min BER values. Different optimization methods are employed in optical WDM systems using optisystem simulation [31]-[36]. Different gain flatness techniques for Erbium-doped fiber amplifier are investigated to test the min BER. The optical fiber length and pump power are optimized to test a required minimum BER, upgrade the optimum gain flatness and reduce the noise figure [37]-[45].

2. MODEL RESEARCH DESCRIPTION

Figure 1 detects an optical communication system block diagram, which consists of a transmitter unit, filter unit, and receiver unit. Figure 2 outlines the schematic view of the theoretical circuit of the optical communication system. Transmitter unit, which is followed by the transmission medium in the air and receiver unit. When there is a sound in front of the speaker the sound movers the layer on the speaker and moves the coil cutting the magnetic field so it produces an electro motive force (EMF). The electrical output signal from the microphone enters the capacitor C1, so it is charged and then release the charge so the signal is amplified and the signal output through the line 6 to the emitted diode that converts the signal into optical signal and transfers it in air.

As shown from the Figure 2(a) the transmitter of the optical communication system. Figure 2(b) the receiver of the optical communication system. Main three blocks of transmitter side are shown in Figure 3. The first block is the microphone, which is connected by a capacitor with value10 µF and ohmic resistance with value 1KΩ. The second block is the integrated circuit, which is an integrated circuit (IC 741) which consists of two input port (2, 3) and one output port. Port No. 2 connected to a resistor with value 1 KΩ. Port No. 3 connected to the capacitor and resistor connected by a microphone. The output port connected to the emitting diode. The third block is the emitting diode connected to two resistors. Main four blocks of the receiver side are shown in Figure 4.

Figure 1. Optical communication system block diagram

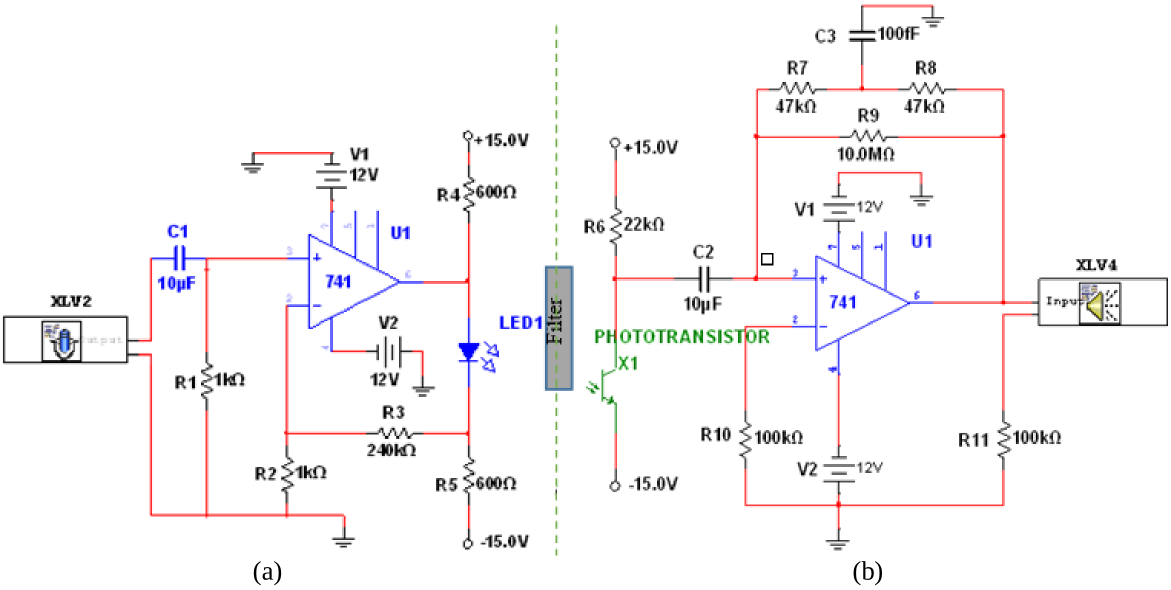

Figure 2. Schematic view of the theoretical circuit of the optical communication system, (a) Transmitter and (b) Receiver

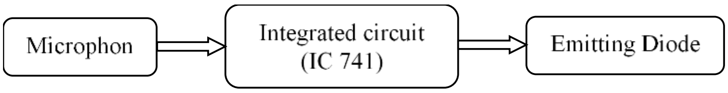

Figure 3. Transmitter unit block diagram

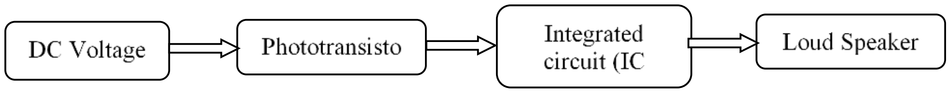

Figure 4. Receiver unit block diagram

The first block is the DC voltage, which contains DC source that supplies +15V DC and -15V DC. The second block is the transistor (TIL 78) connected to a resistor with value 22 KΩ and capacitor with value 10µF. The third block is the integrated circuit (IC 741), which consists of two input ports (2,3) and one output port. Port No. 2 connected to the transistor. Port No. 3 connected to a resistor with value 100 KΩ. The output port connected to the loud speaker and other resistors. The fourth block is the loud speaker, which connected to a resistor with value 100 Ω. The light signal is received and enter the phototransistor TIL-78, which converts the light signal into an electrical signal and enter IC2 through the lines 2&3, which amplifies the signal through the line 6 then enter the speaker that converts the electrical signal to sound. Where Table 1 shows the types of all used resistors, capacitors, and miscellaneous with complete numerical values.

a) Resistance: Resistance plays important role in electronic components as it is the main role is to divide the voltage to make a difference in the voltage between two points. In addition, the resistance value can be fixed or variable depending on its nature. Resistance is independent of the voltage applied on it.

There are some cases at which nonlinear resistance is required; it is called voltage-dependent resistance (VDR). There is another type of nonlinear resistance, which is affected by the temperature, called thermistor. Moreover, the thermistor has two types negative temperature coefficient (NTC) and positive temperature coefficient (PTC). The third type of nonlinear resistance is the photoresistors, which value vary depending on the amount of light falling on it.

Table 1. Typical values for optical Tx./Rx. circuits

Components	Definition	Values
1. Resistances		
R1, R2	Carbon resistance	1 kΩ
R3	Carbon resistance	240 kΩ
R4, R5	Carbon resistance	600 Ω
R6	Carbon resistance	22 kΩ
R7, R8	Carbon resistance	47 kΩ
R9	Carbon resistance	10 MΩ
R10	Carbon resistance	100 kΩ
R11	Carbon resistance	100 kΩ
2. Capacitor		
C1, C2	Chemical capacitor	10 µf
C3	Chemical capacitor	100 µf
3. Miscellaneous		
IC1	Integration circuit	741
IC2	Integration circuit	471
IN	Bipolar diode	TIL32
TR	Phototransistor	TIL78
MIC	Dynamic microphone	
l.S	Speaker	8 ohm

b) Capacitors: Capacitors is one of the most important inactive components to store the electrical charges, also it blocks as current and filtering the signals. The simplest abstract for the capacitor consists of two plates in front of each other, each one is called a polar, and both are isolated and connected to one pair of the capacitor. One of the most common used capacitors is the chemical capacitor as it has high capacity value.

c) Integrated circuits: The integrated circuit is a full electronic circuit on a single chip of semiconductor usually silicon. In this circuit, we use the IC with number 741 which is used globally in different fields such as amplifying, annotation and comparing and it has a lot of advantages that have a high-value input resistance of 1MΩ, Has a low-value output resistance ranging in hundred of ohms, and has high voltage gain value around 10^5.

d) Emitting diode: It is a diode consists of two semiconductors germanium and silicon has two ends, anode, and cathode. After the microphone converts the sound waves to electrical signals, the diode converts these signals into light-emitting signals; the diode TIL 32 is used.

e) Phototransistor: It is an amplifying device consist of three main elements: emitter, base, collector. The phototransistor is used in the receiver circuit as it has the light as input and converts it into an electrical signal.
f) Microphone: A transducer converts the sound into an electrical signal; in the part of the transmitter of the circuit, a dynamic microphone is used.
g) Speaker: A device in the part of the receiver of the circuit, converts the electrical signal into sound and there are four types that are a namely electro-dynamic speaker**,** electromagnetic speaker, electrostatic speaker, and crystal speaker.

3. RESULTS WITH DISCUSSIONS

Communication system consists of a transmitter, medium, and receiver. The input signal, which is introduced through the microphone, is amplified. Light emitting diode (LED), which is placed on the output of the input circuit, emits light that represents the sound from the microphone. The emitted light is transmitted through the vacuum or optical fibbers to the phototransistor, that sense the changes on the received signals, the transistor amplifies the signal to move it to the speaker, that convert the signals into the sound which is heard by the recipient. The process is converting the voice to an electrical signal then light signal and vice versa on the receiver as shown in Figure 2. The transmitter circuit is a pulse width modulation (PWM) circuit connected to infrared (IR) LED when the potentiometer value is changed the on and off times of the LED is changed, means it changes the frequency of transmitted pulses, and the change in illumination of the LED is transmitted through the optical wireless medium as voltage pulses. The printed circuit board (PCB) design for transmitter circuit is clarified in Figure 5.

The receiver circuit uses phototransistor to gather the light pulses from the free space then transform it to an electrical signal. The receiver circuit and the PCB design for the receiver circuit is shown in Figure 6. This circuit can be used only in indoor applications as its range is very short (1~2m) as the available power of transmitter LED is limited based on the clarified values in Table 2. But for using in long-distance the transmitter and power sources must be replaced by other stronger sources. The output of the circuit is measured using an oscilloscope to measure the frequency of the received pulses.

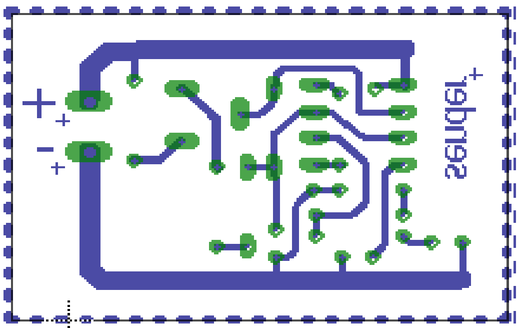

Figure 5. PCB design for the transmitter circuit

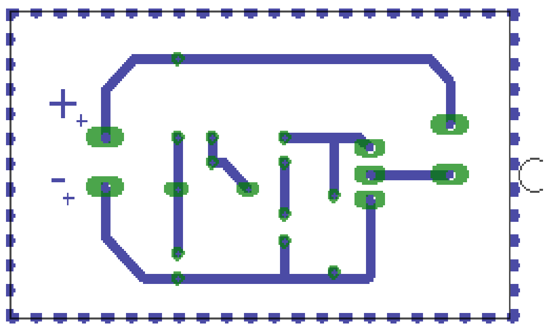

Figure 6. The PCB design for the receiver circuit

Table 2. The component used in both transmitter and receiver

Component	Values	Amount
Phototransistor	--	1
LED IR	--	1
Red LED	--	2
Capacitor	0.47 μF	1
Capacitor	0.1 μF	1
Resistor	100 Ω	2
Resistor	360 Ω	1
Resistor	10 KΩ	4
Potentiometer	50 KΩ	1
Battery	+9 V	2

Figure 7 shows the relation between voltage and time on the oscilloscope channel with time-division equal 0.5 ms and voltage division equal to 2 V while using the 1 KΩ of the potentiometer. The illumination of the LED is low due to the low duty cycle of about 25%. Second Case: using 10 KΩ of the potentiometer.

Figure 8 shows the relation between voltage and time on the oscilloscope channel with time-division equal 0.5 ms and voltage division equal to 2 V while using 10 KΩ of the potentiometer. The illumination of the LED increased due to a higher duty cycle of 50%. Third case: using 50 KΩ of the potentiometer. Figure 9 shows the relation between voltage and time on the oscilloscope channel with time-division equal 0.5 ms and voltage division equal to 2 V while using 50 KΩ of the potentiometer. The illumination of the LED increased due to a higher duty cycle with high frequency.

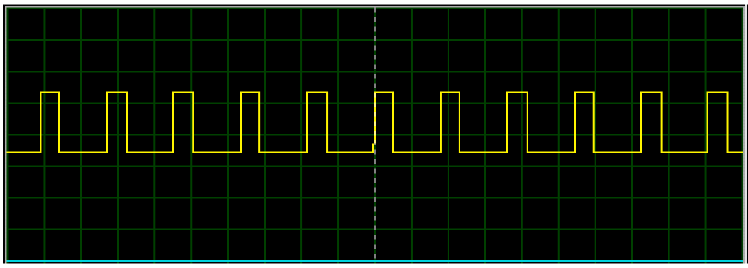

Figure 7. Voltage versus time at the receiver using 1 KΩ of the potentiometer

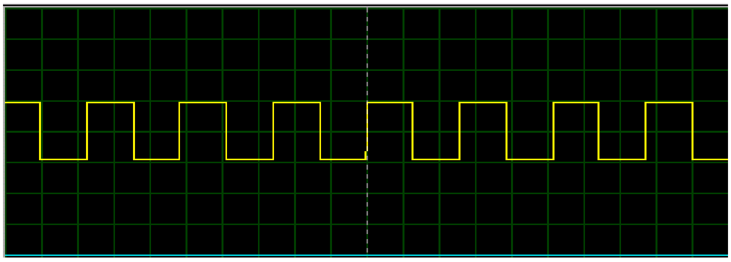

Figure 8. Voltage versus time at the receiver using 10 KΩ of the potentiometer

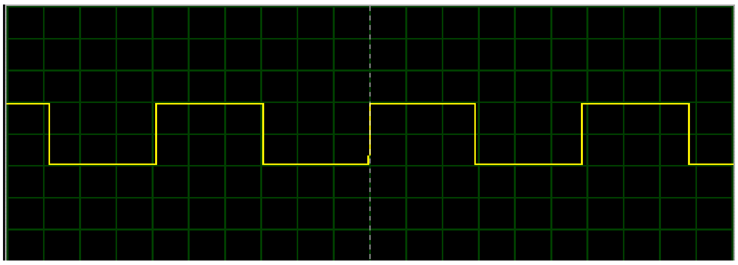

Figure 9. Voltage versus time at the receiver using 50 KΩ of the potentiometer

4. CONCLUSION

In summary, free-space optical (FSO) is a trending field that is rising so fast to replace electromagnetic waves in communication. A theoretical circuit as an example and modified it to fit and work in communication purposes are presented. Simulation is used and then practical work is done, where printed board circuit is designed, using LED as transmitter and phototransistor as a receiver, also using variable resistance to change voltage sent to the light-emitting diode that indicates the change in transmitted signal.

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